UNIVERSITÀ DEGLI STUDI DI FERRARA
DIPARTIMENTO DI ECONOMIA ISTITUZIONI TERRITORIO
Corso Ercole I d'Este, 44 – 44100 Ferrara

Quaderno n. 24/2006

November 2006

Inequality or Strategic Uncertainty?
An Experimental Study on Incentives and Hierarchy

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Abstract

We run an experiment based on a model in which agents have the option of reducing the probability of failure by investing towards their decisions. In this case, asymmetric (unequal) benefit schemes appears to enhance agents' productivity, compared with schemes in which benefits are equally distributed across agents. Our evidence also shows how discrepancy between theory and evidence can be explained in terms of social preferences and social norms of reciprocity.

JEL Classification Numbers: C90
Keywords: experimental economics, optimal incentive design, sequential decision-making.

*The authors are grateful to Lola Collado, Ricardo Martinez, Raffaele Miniaci, Juan D. Moreno-Ternero, Marco Piovesan, and Fernando Vega Redondo for their helpful comments and suggestions. Usual disclaimers apply. Financial support was provided by the Generalitat Valenciana (GV06/275), CICYT (BEC2001-0980), by MURST, under the project "Organizzazione produttiva, retribuzioni e nuove forme di occupazione" (Università di Ferrara) and by the Instituto Valenciano de Investigaciones Económicas (IVIE).

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1 Introduction

The role of non-pecuniary effects on agents' behavior in various experimental games has been extensively debated in the literature of both behavioral and experimental economics. Since the seminal contributions of Fehr and Schmidt [7] and Bolton and Ochsenfeld [3], many scholars have argued that players in a game display strategic behavior that is inconsistent with simple (monetary) payoff maximization. Rather, they try to maximize a more complex function that takes into account not only one's payoff but also other players' payoff. Equality seems to be a key notion in these arguments: players have "social" (i.e. distributional) preferences that display inequality aversion.

In this paper, we report experimental results on a strategic environment in which *inequality seems to facilitate cooperation*, rather than impede it. The strategic environment can be described as a special case of the model developed in Winter [13].[1] A project is operated by n agents each of which is responsible for a different task. Agents decide sequentially whether they contribute toward the success of their task at a cost c, which is common to all agents. If an agent contributes, her task succeeds with certainty. If she fails to contribute the task succeeds only with probability α <1. If all tasks end successfully, agent i receives a reward of b_i; if one of the n tasks fails, all agents receive no rewards.

Winter's [13] main theoretical finding is that *a vector of unequal rewards breeds more contributions by all agents than a payoffs that allocate the total reward equally between them.* Notice that his $\alpha-$technology makes each agent ex-ante marginal productivity equal, which makes unequal rewards particularly hard to digest. Still, agents' performance under inequality is better than that under equal rewards. In fact, subjects' behavior in this game is to a large extent consistent with the theory and intuition provided by Winter [13] for more general environments: the unequal environment facilitates coordination among the agents which, in turn, allows both of them to contribute. In the unequal environment, the agent with the higher reward has an increased incentive to contribute. Since the contribution by one agent makes the contribution by the others more effective, the higher reward that one agent receives serves as an assurance for the other agents that she will not be the only contributor, which motivates their reciprocal con-

[1]See also Winter [14].

tribution. By contrast, in a symmetric environment where agents' rewards are identical, this tacit coordination is not available and, consequently, all agents ultimately contribute less. To put it differently, Winter's [13] model highlights the tension between robustness and fairness: *fairness can only be obtained at the expense of robustness to strategic uncertainty.*

The role of asymmetry in boosting agents' incentives to contribute is quite intuitive. It relies on the complementarity between the tasks and on the fact that one agent's high stake in the project success motivates the other agent to contribute. In Winter [13], it is shown that an optimal incentive mechanism (i.e. one that yields contribution by all agents as a unique equilibrium and does so with minimal total reward) must discriminate among the agents.

It may be worth noticing at this point that Winter's [13] result crucially depends on two assumptions:

1. agents' preferences only depend (in a linear fashion) on the monetary rewards they receive. This implies that agents *(i)* are assumed to be risk neutral and that *(ii)* preferences are not interdependent across agents;

2. when the game is played sequentially, agents correctly apply backward induction when they make their decisions (in other words, agents are *sequentially rational and they know that their opponents are also sequentially rational).*

In these respects, there is already substantial experimental evidence that cast doubts on the empirical content of *both* (widely used in applied industrial organization) assumptions.[2] On the other hand, this evidence also shows that empirical content varies significantly depending on the strategic context to which it is applied. The most controversial experimental evidence on these issues comes from *public good games* and *games of reciprocity* (such as ultimatum or trust games).[3] In these cases, the debate has focused, together with social preferences, to social norms of reciprocity as determinants of subjects' behavior.

[2]As for backward induction, see Binmore *et al.* [1] and the literature cited therein. As for interdependent utilities, see, among others, Ochs and Roth [10] and Costa Gomes and Zauner [6].

[3]See, for example, Camerer and Fehr [5].

To test the empirical validity of these alternative explanations (and the robustness of Winter's [13] conclusions compared to alternative benchmarks), we do not only collect experimental evidence on Winter's [13] basic model, but also test in the lab the efficiency and behavioral properties of alternative mechanisms, as follows.

1. First, we run sessions in which *benefits are uniform across agents* (and the total sum of benefits being equal to that of Winter's [13] optimal solution). This provides the most natural alternative to test the trade-off between inequality and strategic uncertainty.

2. In addition, we look at schemes which rely on a less demanding solution concept that subgame perfection, namely *Nash equilibrium.* In this case, asymmetry across benefits is even higher (as higher should be robustness to strategic uncertainty since, under this mechanism, we rule out the possibility of a Nash equilibrium in which all agents do not invest).

3. We also collect evidence of a variant of the original model in which, like in Winter [14], *hierarchy is absent* (insofar all agents are asked to move simultaneously).

4. Last, but not least, we also check for *group size effects,* that is, we investigate on how an increase in the group size (and therefore, in the overall complexity of the game subjects play) affects the behavioral properties of the model.

Our experimental study yields the following conclusions. First, we observe that, despite of a significant proportion of inefficient outcomes, Winter's [13] asymmetric solution is always more efficient than the equally expensive egalitarian one. This is exactly because higher rewards on behalf of one agent has positive externalities on the probability of investing of the others. Even better results can be achieved by way of schemes which rely on Nash equilibrium (i.e. using schemes in which robustness to strategic uncertainty is supposingly even higher, together with the induced inequality). Our study also highlight a (non strategic) correlation between benefits' levels and propensity to invest and (to our surprise) better efficiency of simultaneous mechanisms. Finally, our evidence also shows how discrepancy between theory and evidence can be explained in terms of *social preferences* and *social norms of reciprocity.*

The remainder of the paper is arranged as follows. Section 2 provides a brief synopsis of the theory underlying the experiment, as developed in Winter [13]. Section 3 describes the experimental design, while Section 4 summarizes the descriptive results and investigates subjects' behavior using panel data estimations. Finally, Section 5 concludes, followed by an appendix containing the experimental instructions.

2 The model

In what follows, we shall briefly introduce the games object of our experimental study.

2.1 The basic model

The organizational project involves n activities performed by n agents who are ordered increasingly according to their hierarchy position in the organization. That is, agent $i+1$ *supervises* agents $i, i-1, \ldots, n$. The consequence of supervision is purely informational. That is, i supervises j means that agent i can observe the behavior of agent j and in particular the effort that has been exerted by agent j towards the performance of her activity. On the contrary, subordinates cannot similarly observe the behavior of their bosses.

This relation dictates the order of moves in a sequential game of perfect information. Players act sequentially in the order $1, 2, ..., n$. Each agent in her turn decides whether to invest towards the performance of her activity. This investment can be interpreted as an acquisition of costly information relevant to that agent's decision making. We denote by $\delta_i \in \{0, 1\}$ the investment decision of agent i, where δ_i =1 (0) if agent i does (not) invest. The cost of investment in the model is c and is assumed to be constant across agents. [4]

Each agent, before making her investment decision, observes the decision of all her predecessors (i.e., her subordinates). Each agent's activity results in either success or failure. If agent i invests, i.e., $\delta_i = 1$, then her activity is successful with probability 1. However, if $\delta_i = 0$, her success probability

[4] Winter [13] also considers the case of asymmetric costs.

is $\alpha \in (0,1)$.[5]

The events of successful activities are independent across agents. The project terminates successfully if and only if all activities have been performed successfully. If the project fails, then all agents receive a payoff of zero. If the project succeeds, then agent i receives a benefit, $b_i > 0$. Thus agents' benefits are conditional only on the project's realization and not on individual investment decisions. This assumption clearly recalls the classic principal-agent problem, here studied in presence of a formal hierarchy across agents. Unlike the classical principal-agent problem, all agents are assumed to be expected benefit maximizers (i.e. risk-neutral).

More precisely, game's payoffs can be calculated as follows. Let $\delta = (\delta_1, \ldots, \delta_n) \in \{0,1\}^n$ denote the action combination taken by all agents. Then, agent i's expected payoff is given by

$$\pi_i(\delta) = b_i \alpha^{(n - \sum_j \delta_j)} - \delta_i c.$$

Denote by $G(b)$ the extensive form game induced by the vector of benefits $b = (b_1, \ldots, b_n)$. In the sequel we shall solve this game by characterizing its subgame perfect equilibria (SPE). The principal wishes to design a mechanism that induces all agents to invest (in equilibrium). A mechanism is an allocation of benefits in case of success, i.e., a vector b . We say that the mechanism b is investment-inducing (INI) if all the SPE of $G(b)$ entail investment by all agents, i.e., $\delta = (1, \ldots, 1)$. In addition, the principal attempts to achieve this goal with minimal benefit distribution. We will say that an INI mechanism b^* is optimal if

$$\sum_{i=1}^{n} b_i^* \leq \sum_{i=1}^{n} b_i$$

for every other INI mechanism b.

3 The experimental design

In what follows, we describe the features of the various experimental treatments in detail.

[5] All experimental treatments are characterized by a uniform probability of success, α. Winter [13] also explores the case of asymmetric probabilities across players.

3.1 Subjects

The experiment was conducted in 12 sessions in May, 2004. A total of 144 students (12 per session) were recruited among the undergraduate student population of the University of Alicante -mainly, undergraduate students from the Economics Department with no (or very little) prior exposure to game theory. Each session lasted for approximately one hour. Instructions were provided by a self-paced, interactive computer program that introduced and described the experiment. Copies of written instructions (identical to the instructions on the screen) were also distributed.

The 12 experimental sessions were computerized. Instructions were read aloud and we let subjects ask about any doubt they may have had.[6] In the first (last) 6 sessions, subjects played in groups with $n = 2$ ($n = 3$). Each experimental session involved $12/n$ groups of n subjects playing 20 rounds of a sequence of 3 mechanisms. The order of mechanisms varied among sessions, to control for inter-treatment learning effects. Therefore, all experimental sessions consisted of $20 \times 3 = 60$ rounds in total.[7]

In all rounds of each session subjects played anonymously with varying opponents. Subjects were informed that the composition of their group would change at every round, but their agent position (i.e., their position in the hierarchy) would remain the same throughout the session. At the end of each round, each agent knew whether the project was successful for that round and the associated monetary payoff.

3.2 Payoffs

All monetary payoffs in the experiment were expressed in Spanish Pesetas (1 euro is approx. 166 ptas.).[8] All subjects received 500 Spanish pesetas

[6]The experiment was programmed and conducted with the software z-Tree (Fischbacher [8]). The complete set of instructions, translated into English, can be found in the Appendix.

[7]With the only exception of 2 sessions in which subjects played a sequence of 4 treatments (see Section 3.8 below).

[8]It is standard practice, for all experiments run in Alicante, to use Spanish ptas. as experimental currency. The reason for this design is twofold. First, it mitigates integer problems, compared with other currencies (USD or Euros, for example). On the other hand, although Spanish pesetas are no longer in use (substituted by the Euro in the year 2000), Spanish people still use Pesetas to express monetary values in their everyday life. In this respect, by using a "real" (as a opposed to an artificial) currency, we avoid the problem

(3 euros approx.) to show up. Average earnings were 3250 pesetas (19.5 euros approx.), including the participation fee.

3.3 Group size

As we mentioned previously, we run mechanisms with different group size. In particular, we collected evidence on the "basic model" (the optimal INI mechanism) both with $n = 2$ and $n = 3$, selecting for the other mechanisms one group size or the other depending on the issues at stake.

3.4 Treatments

Figure 1 summarizes the three different benefit schemes tested in the experiment: INI, UNI and NASH.

n=2	b_1	b_2	
INI	$\frac{c}{1-\alpha^2}$	$\frac{c}{1-\alpha}$	
UNI	$\frac{c(2+\alpha)}{2(1-\alpha^2)}$	$\frac{c(2+\alpha)}{2(1-\alpha^2)}$	
NASH	$\frac{c}{\alpha(1-\alpha)}$	$\frac{c}{1-\alpha}$	
n=3	b_1	b_2	b_3
INI	$\frac{c}{1-\alpha^3}$	$\frac{c}{1-\alpha^2}$	$\frac{c}{1-\alpha}$
UNI	$\frac{c(\alpha^3+3\alpha^2+4\alpha+3)}{(1-\alpha^2)(\alpha^2+\alpha+1)}$	$\frac{c(\alpha^3+3\alpha^2+4\alpha+3)}{(1-\alpha^2)(\alpha^2+\alpha+1)}$	$\frac{c(\alpha^3+3\alpha^2+4\alpha+3)}{(1-\alpha^2)(\alpha^2+\alpha+1)}$
NASH	$\frac{c}{\alpha^2(1-\alpha)}$	$\frac{c}{\alpha(1-\alpha)}$	$\frac{c}{1-\alpha}$

(1)

Figure 1 Benefit schemes for all mechanisms

As we just mentioned, INI corresponds to the solution of the basic model of Section 2. In this case, the unique SPE is outcome equivalent to the optimal solution in which all agents invest. This game has also a (not subgame perfect) Nash equilibrium in which nobody invests.

In UNI the sum of benefits is as in INI but it is distributed uniformly across agents. In this case, the unique (subgame perfect) Nash equilibrium is such that all agents should not invest at every information set.

Finally, in NASH, benefits are distributed so that all Nash equilibria are outcome equivalent to the optimal solution. Notice that this scheme is

of framing the incentive structure of the experiment using a scale (e.g. "Experimental Currency") with no cognitive content.

more costly than INI, to provide first-movers enough incentives to invest even if followers do not. More precisely, in NASH, $\mathbf{b}_1$ is set high enough to induce investment by agent 1 even if all other agents in the hierarchy do not invest in any information set; $\mathbf{b}_2$ is set high enough to induce investment by agent 2 even if all other agents in the hierarchy except agent 1 choose not to invest in any information set, and so on. In consequence, in NASH, the ranking of benefits is reversed compared with INI, while b_n, the last agent's benefit, is the same than in INI.

3.5 Benchmark mechanisms

In what follows, we denote by *benchmark games* the INI, NASH and UNI mechanisms with $n = 2$ and $\alpha = 0.5$. The remaining mechanisms for which we have collected evidence will be used as terms of comparisons of these benchmarks.

3.6 Simultaneous *vs.* sequential mechanisms

All benchmark mechanisms involve a sequential game of perfect information. In these mechanisms, subjects were informed in each round about the action of their subordinates before they were asked to make their decision. However, some experimental treatments modify this structure by simply considering a purely *flat organization.* In this case, there is no hierarchy: agents take simultaneously their decisions without any prior knowledge of the decision of other members in their group. For simplicity, we have collected evidence of simultaneous mechanisms only for 2-player games.

The simultaneous version of INI, denoted by SINI hereafter, unlike its sequential counterpart, has a unique Nash equilibrium in which all agents should not invest. The simultaneous version of UNI, denoted by SUNI hereafter, has a unique Nash equilibrium is neither agent invests. Finally, the simultaneous counterpart of NASH, denoted by SNASH hereafter, has a unique Nash equilibrium in which all agents should invest. This is because, in this case, not investing is a strictly dominated strategy for agent 1. Thus, the induced game can be solved by the iterated deletion of strictly dominated strategies.

3.7 Risk aversion

The theoretical model assumes that agents are risk neutral. This assumption is needed to calculate the "efficient" optimal INI scheme as the cheapest benefit profile that would induce a group of expected profit maximizers agents to invest. Clearly, if agents were risk averse (lovers), the corresponding optimal INI scheme would be cheaper (more expensive).

We can use our experiment to investigate on this issue by means of two alternative approaches. First, recall that, in the benchmark treatments, we set $\alpha = 0.5$. To test subjects' risk attitude, we check whether changes in α yield changes in subjects' behavior. To this aim, we consider some additional 3-player mechanisms in which $\alpha = 0.25$. Second, we have considered additional treatments (also for 3-player games) in which agents' payoffs are no longer random, but correspond to the expected monetary rewards subjects are due to receive depending on the number of their group members that invest, minus (if any) investment costs. Obviously, for these treatments, the concept of "successful project" has no meaning, because the outcome of the project is a deterministic function of the decisions taken by the agents. This is why we presented deterministic treatments without any *frame*, that is, without any story behind. In unframed treatments subjects were introduced to the game by simply describing the corresponding (deterministic) payoff function, without any reference to "projects", "investments", "costs" or "probability of success".

3.8 Sequence of mechanisms

The following Figures 2 and 3 summarize the sequence of mechanisms characterizing the 12 experimental sessions. As we mentioned earlier, subjects in sessions with $n = 2$ (Figure 2) experienced 3 out of the 7 possible mechanisms, always starting with a simultaneous mechanism.

SESSION	**TR**$_1$	**TR**$_2$	**TR**$_3$
FR_2^1	SUNI	SNASH	INI
FR_2^2	SNASH	SINI	UNI
FR_2^3	SINI	SUNI	NASH
FR_2^4	SINI	UNI	INI
FR_2^5	SNASH	INI	UNI
FR_2^6	SUNI	NASH	INI

(2)

Figure 2 - Experimental sessions with $n = 2$

As Figure 3 shows, subjects in sessions with $n = 3$ (Figure 3) experienced 3 out the 9 possible mechanisms in the first 4 sessions and 4 out of the 9 possible mechanisms in the last 2 sessions. We shall refer to the subindex FR and UNFR to distinguish between framed and unframed sessions respectively, while the corresponding value of α is reported as a superindex.

SESSION	$\mathbf{TR}_1$	$\mathbf{TR}_2$	$\mathbf{TR}_3$	$\mathbf{TR}_4$	
FR_3^7	$INI_F^{.25}$	$UNI_F^{.25}$	$INI_F^{.5}$	N/A	
FR_3^8	$UNI_F^{.25}$	$INI_F^{.25}$	$UNI_F^{.5}$	N/A	
FR_3^9	$UNI_F^{.5}$	$INI_F^{.5}$	$NASH_F^{.5}$	N/A	(3)
FR_3^{10}	$INI_F^{.5}$	$NASH_F^{.5}$	$UNI_F^{.5}$	N/A	
UNFR_3^{11}	$INI_U^{.5}$	$UNI_U^{.5}$	$INI_U^{.25}$	$UNI_U^{.25}$	
UNFR_3^{12}	$INI_U^{.25}$	$UNI_U^{.25}$	$INI_U^{.5}$	$UNI_U^{.5}$	

Figure 3 - Experimental sessions with $n = 3$

4 Results

In reporting our experimental results, we begin by looking at the efficiency properties of all experimental mechanisms. Later, we also describe their behavioral properties, reporting subjects' aggregate behavior at each information set. We conclude by developing a panel data analysis to investigate more in depth the issues of interdependent utilities, hierarchy architecture, reciprocity and risk aversion.

4.1 Efficiency

Figures 4 and 5 compare the various experimental mechanisms with respect to their efficiency properties, that is, their ability to induce subjects to invest. We do so by reporting five indicators: the relative frequency of *successful projects* (*succ*), *expected successful projects* (*esucc*), *first-best* (*fb*), *last-best* (*lb*) and *average frequency of contributors* (*contr*) for the

2-player and 3-player mechanisms respectively.

	INI	NASH	UNI	SINI	SNASH	SUNI
succ	.64	.61	.52	.73	.67	.58
esucc	.59	.64	.56	.75	.70	.62
fb	.36	.40	.30	.53	.44	.34
lb	.38	.23	.39	.08	.11	.20
contr	.49	.58	.46	.73	.67	.57

(4)

Figure 4: Outcomes distributions in 2-player mechanisms

	$\text{INI}_F^{.5}$	$\text{NASH}_F^{.5}$	$\text{UNI}_F^{.5}$	$\text{INI}_F^{.25}$	$\text{UNI}_F^{.25}$	$\text{INI}_U^{.5}$	$\text{UNI}_U^{.5}$	$\text{INI}_U^{.25}$	$\text{UNI}_U^{.25}$
succ	.43	.65	.43	.50	.55	.33	.16	.22	.11
esucc	.43	.60	.46	.51	.54	.33	.16	.22	.11
fb	.24	.34	.26	.48	.48	.22	.01	.20	.08
lb	.39	.05	.23	.28	.22	.67	.83	.65	.80
contr	.42	.68	.50	.58	.64	.26	.07	.25	.14

(5)

Figure 5: Outcomes distributions in 3-player mechanisms

By "successful projects" we denote the relative frequency of matches in which the project was successful. Recall that, this occurs only when all agents did their task correctly and, for a given agent, this event has a probability of (α) 1 when (not) investing. Also notice that, from the principal's viewpoint, this is the only information available. By "expected successful projects" we denote the *ex-ante* probability of obtaining a successful project given the aggregate distribution of agents' behavior. This indicator has the advantage of eliminating the possible bias in the frequency of *actual* successful projects due to the randomness of the process. Nevertheless, e*succ* has also its drawbacks, as it might not coincide with the actual history subjects are observing along the experiment (which may influence their behavior in many different ways).[9] By "first-best" we denote the relative frequency of matches in which all agents in a group have invested. By "last-best" we denote the relative frequency of matches in which no group member decided to invest. Finally, by "*average frequency of contributors* " (*contr)* we denote the relative frequency of agents in a group who decided to invest.

[9]Obviously, for the unframed treatments, the values of *succ* and *esucc* must coincide.

4.1.1 Benchmark mechanisms

We begin by comparing the results obtained in the three benchmark mechanisms, that is, the 2-player sequential mechanisms INI, NASH and UNI. If we compare efficiency across mechanisms, we can see that *esucc* is highest in NASH, followed by INI and finally by UNI. The same ranking is preserved for all the other efficiency indicators except for *succ,* where INI is more efficient than NASH, although this difference is not statistically significant.[10] In other words, the efficiency of a mechanism seems to be positively correlated to the induced inequality (compare INI with UNI) and to the overall benefits distributed (compare INI with NASH).

4.1.2 Simultaneous mechanisms

If we compare the efficiency measures of simultaneous *vs.* sequential mechanisms we observe that simultaneous mechanisms are in general more efficient. This is particularly surprising in the case of INI, since, the (equilibrium) strategic properties of INI and SINI are precisely the opposite, insofar the unique SPE of INI (SINI) would require all agents (not) to invest. Similar considerations hold when we compare NASH and its simultaneous counterpart SNASH. In this case, despite the difference in the game-form, the strategic properties of NASH and SNASH are essentially the same but the experimental evidence shows that SNASH is significantly more efficient. Also notice that, for any given benefit scheme, simultaneous mechanisms are particularly effective in reducing (up to 4 times as much in the case of INI) the relative frequency of last-best outcomes, rather than

[10] In this section, to test for statistical significance, we adopted the following method. Define X_i^j as a random variable which is 1 if the $i-$th match of experiment j is first-best efficient and 0 otherwise, with $j = 0, 1$. Thus, the distribution of X_i^j is Binomial $B(1, p^j)$. If we assume that all N repetitions (i.e. matches) of each treatment correspond to independent and identically distributed (i.i.d.) observations, then $\bar{p}^j \equiv \frac{\sum_{i=1}^N X_i^j}{N}$ has normal asymptotic distribution $N(p^j, \frac{p^j(1-p^j)}{N})$. If the null hypothesis is true, then

$$Z \equiv \frac{\bar{p}^1 - \bar{p}^0}{\sqrt{\frac{\bar{p}^1(1-\bar{p}^1)}{N} + \frac{\bar{p}^0(1-\bar{p}^0)}{N}}}$$

is asymptotically distributed as a standard normal random variable. Hence, Z can be used as test statistic. Throughout the paper, the threshold for statistical significance is set at the level of 5%.

increasing the relative frequency of first-best outcomes.

If we look at the relative performance of simultaneous mechanisms, we get a similar picture than for the benchmark case: once again, *asymmetric mechanisms are far more efficient.* Somehow surprisingly, SINI ranks first for all our efficiency indicators, followed by SNASH and SUNI, with the difference in efficiency between SINI and SUNI (SNASH) (not) always statistically significant.

4.1.3 Group size

To analyze how changes in the group size affects outcome distributions, we compare the results of the benchmarks INI, NASH and UNI with those of their corresponding 3-player mechanisms, that is, INI_F^5, NASH_F^5 and UNI_F^5. In this respect, INI has 59% of expected successful outcomes, whereas this frequency falls to 43% when we consider the larger group mechanism (this difference is statistically significant at the 1% confidence level). Thus, for INI, we observe that *applying a further round of backward induction has a significant impact on the incentive scheme's efficiency.* Also for UNI, we observe a significantly higher rate of expected success when $n = 2$ (56%) than when $n = 3$ (46%). In contrast, efficiency of NASH seems more robust to group size, with a higher (not significant) proportion (64%) of expected successful outcomes with $n = 2$ than with $n = 3$ (60%). For the remaining efficiency measures (except for *lb*), we observe that all mechanisms display higher efficiency when $n = 2$, although this difference is not always significant (except for *contr* in UNI). For example, if we observe the results obtained for first-best, again, efficiency of INI seems very sensitive to group size (36% the in small group mechanisms whereas 24% in the large group mechanisms), while the same does not occur in the case of NASH and UNI.

To summarize: robustness to strategic uncertainty (typical of our asymmetric mechanisms) is stronger, the larger the group size (with this latter effect being stronger with our NASH benefit scheme)

4.1.4 Risk aversion

To analyze the effects of changes in α, we first look at the framed treatments. Here we notice that changes in α are important. In particular, both for INI and UNI, we observe (significant) higher efficiency when α is equal to 0.25. A possible explanation for this evidence is that subjects are risk averse and therefore show a higher propensity to invest when the probability of success in case of not investing is lower. Similar considerations hold when we compare, for a given α, the efficiency of framed (stochastic) *vs.* unframed (deterministic) treatments. In this case, outcome distributions (with the sole exception of UNI) are in general significantly more efficient in the framed treatments. On the other hand, as shown in Figure 1, (expected) benefits increase with α. As we previously mentioned, subjects' propensity to invest seems positively correlated with benefit level. In this respect, if we compare the results obtained in the unframed (deterministic) treatments depending on the value of α, we see that efficiency *increases* with α. Clearly, this result should not depend on the degree of subjects' risk aversion since, in the unframed treatments, subjects always receive just their expected profits.

4.2 Behavior

We now move on to analyze the behavioral properties of the various mechanisms. As Figure 6 shows, we employed three different game-forms: one extensive form (Γ_1) and one strategic (Γ_2) for the 2-player mechanisms, and a unique extensive form (Γ_3) for all 3-player mechanisms.

(6)

Figure 6: The experimental game-forms

Let μ_i^k be agent i's (average population) behavioral strategy at information set k, defined as the relative frequency with which subjects in agent i's position invest at information set k.

4.2.1 Benchmark mechanisms

Figure 7 reports subjects' aggregate behavior for the three benchmark mechanisms, INI, $NASH$ and UNI.

STR. / TREATM.	μ_1^1	μ_2^1	μ_2^2
INI	.50	.24	.72
$NASH$	.73	.15	.54
UNI	.51	.22	.57

(7)

Figure 7: Aggregate behavior in the benchmark mechanisms

Again, the first striking evidence is the difference between actual behavior and theoretical prediction (take, for example, the case of μ_1^1 in INI, whose value -.5- is exactly half of the corresponding equilibrium level). This evidence notwithstanding, we also observe significant changes in behavior depending on the benefit scheme employed. For example, the relative frequency of investment decisions for subjects in agent 1's position is much higher in NASH (73%) than in any other benchmark mechanism (50% in INI and 51% in UNI respectively). This is certainly related with the fact that, in NASH, $\mathbf{b}_1$ is the expected monetary profit maximizing action, independently on what agent 2 does. In other words, NASH solves the problem of strategic uncertainty by providing agent 1 with sufficient rewards not to worry about agent 2's response. From this evidence, we get to the conclusion that the (comparatively) higher efficiency of Nash is mainly due to agent 1's behavior. Focusing now on agent 2's behavior, we find that, along the "efficient" path, the relative frequency of agents 2 who invest (μ_2^2) is significantly higher in INI (72%) than in UNI (57%) or NASH (54%). The difference between INI and NASH is particularly surprising since b_2 is the same for both mechanisms. However, player 2 is the agent with the highest salary in the hierarchy in INI, whereas in NASH the highest salary is given to player 1. This result suggests that individuals have social preferences, and therefore their behavior depends not only on their own benefits but also on the benefits of others.

4.2.2 Simultaneous *vs.* sequential mechanisms

As for the simultaneous mechanisms, subjects' aggregate behavior is summarized in Figure 8.

STR. / TREATM	μ_1^1	μ_2^1
SINI	.74	.72
SNASH	.73	.60
SUNI	.57	.58

(8)

Figure 8: Aggregate behavior in the 2-player simultaneous mechanisms

If we compare the behavioral properties of sequential and simultaneous mechanisms, we observe that, with the exception of NASH, agents 1 invest significantly more in simultaneous mechanisms. This evidence might indicate that symmetric information has generally a positive effect in agent 1's decision to invest. Similar considerations hold when we look at agent 2. Here we notice that the relative frequency of investment decision in simultaneous mechanisms (μ_2^1 of Figure 8) *is never statistically different from* the relative frequency of investment decision along the efficient path in sequential mechanisms (that is, μ_2^2 in Figure 7). In other words, in simultaneous mechanisms, *agent 2 behaves as if she had observed agent 1 investing beforehand.* This effect yields an overall higher frequency of investment on behalf of agent 2 in all simultaneous mechanisms which, in turn, yields higher efficiency.

4.2.3 Group size

Aggregate statistics of behavioral strategies for 3-player mechanisms are summarized in Figure 9.

STR. / TREATM.	μ_1^1	μ_2^1	μ_2^2	μ_3^1	μ_3^2	μ_3^3	μ_3^4
$INI_F^{.5}$	.40	.28	.71	.10	.32	.60	.83
$NASH_F^{.5}$	.95	0	.72	0	.20	N/A	.49
$UNI_F^{.5}$	.58	.34	.60	.16	.23	.43	.73
$INI_F^{.25}$	.61	.21	.85	.12	.20	.23	.93
$UNI_F^{.25}$	.71	.20	.86	.05	.38	.44	.78
$INI_U^{.5}$	.29	.02	.74	.04	.08	.50	1
$UNI_U^{.5}$	.12	.03	.74	.04	.13	0	.25
$INI_U^{.25}$	.29	.05	.70	.04	0	0	1
$UNI_U^{.25}$	.18	.03	.79	0	0	0	.55

(9)

Figure 9: Aggregate behavior in the 3-player mechanisms

We begin by comparing the behavioral properties of the three benchmarks INI, UNI and NASH with their 3-player counterparts $\text{INI}_F^{.5}$, $\text{UNI}_F^{.5}$ and $\text{NASH}_F^{.5}$. Again, in $\text{INI}_F^{.5}$ and $\text{UNI}_F^{.5}$ ($\text{NASH}_F^{.5}$), along the efficient path, subjects invest more (less) the higher their position in the hierarchy (40%, 71% and 83% for $\text{INI}_F^{.5}$, 58%, 60% and 73% for $\text{UNI}_F^{.5}$ and 95%, 72% and 49% for $\text{NASH}_F^{.5}$ respectively).Notice that player 3 in INI invests significantly more than in NASH (83% versus 49%) even though b_3 is the same in both mechanisms. This again may be a consequence of subjects' social preferences.

The comparison between the experimental evidence between INI and INI_F^5 also challenges Winter's [13] theoretical model on a different ground. If agents behave consistently with backward induction, they should display identical behavior in INI and in the subgame of INI_F^5 starting from the decision node in which agent 2 has observed agent 1 investing. This assumption, often termed as *subgame consistency,* is strongly rejected by our experimental evidence.[11] Players 2 and 3 invest significantly more in INI_F^5 than agents 1 and 2 in INI. Again, this, together with the evidence that in UNI_F^5 individuals invest more the higher their position in the hierarchy (even though their benefis are equal), may be due to the presence of some reciprocal component in late-mover behavior.

To summarize: adding one additional player in the hierarchy decreases significantly INI's overall efficiency. In other words, applying a further round of backward induction has a significant negative impact on the propensity to invest (this effect being particularly strong for agent 1). In contrast, efficiency in Nash seems much more robust to changes in group size. Again, this is mainly due to agent 1's behavior: $\mu_1^1 = .95$ for NASH_F^5 and only .4 in INI_F^5.

4.2.4 Risk aversion

To analyze the effect of changes in α on agents' behavior we compare the behavioral properties of INI_F^5 and UNI_F^5 with those of INI_F^{25} and UNI_F^{25} (see Figure 9). In line with the discussion in Section 4.1.4, we observe a negative correlation between α and the propensity to invest. By the same token, for a given α, agents generally invest more in framed than in unframed treatments both in and out the efficient path (with few exceptions, such as the case of agent 3 in INI). This evidence, consistent with risk aversion, makes always higher overall efficiency in framed treatments.

To summarize: We have also found evidence consistent with the hypothesis that agents are risk averse. This last issue is less problematic for the model because, even if the principal cannot measure the (possibly heterogeneous) degree of risk aversion of each individual subject (necessary to achieve optimality), setting benefits under the assumption of risk neutrality

[11]The term subgame consistency is borrowed from Binmore *et al.* [1], who also collect contradicting evidence in the case of the classic Ultimatum Game.

would put the principal on the "safe side". In fact, if agents are risk averse the "theoretical" benefit schemes required to generate optimal investment inducing mechanisms should be cheaper.

4.3 Social preferences vs Social norms revisited: a simple panel data estimation

Throughout this paper, we made several times reference to *social preferences* and *social norms* (i.e. reciprocity) effects in explaining the discrepancy between theory and evidence in subjects' behavior. Our descriptive statistics unambiguously show significant correlations between other group members benefits and actions and investment decisions to reject the hypothesis that agents only look at the monetary rewards they expect to gain in the game. We also observe reciprocal behavior in some cases. Given this, the next question would then be: *which of the two effects is predominant*? To answer this question, we may first notice that, no matter how you define them, the distinction between social norms and social preferences is fuzzy. After all, the "willingness to (costly) reward (punish) friendly (hostile) actions" -this is how Camerer and Fehr [5] define reciprocity- may simply reflect a concern in other agents' payoff, that is, may simply be considered as the consequence of the existence of a system of values based on social preferences.

Social preferences have been the object of many experimental papers, mainly in the context of the Ultimatum game.[12] Among the various formalizations proposed by the literature, we shall follow more closely the approach followed by Costa-Gomes and Zauner [6]. In their paper, they consider a utility function whose deterministic part (supplemented by an error designed to facilitate empirical application) is given by

$$u_i(\pi_i, \pi_j) = \gamma_1 \pi_i + \gamma_2 \pi_j, \tag{10}$$

where π_i (π_j) defines agent i (opponent)'s monetary payoff in the game.

In what follows, we shall only consider observations of 3-player mechanisms. More precisely, let $\pi_3^k(\delta_3)$ ($\pi_{-3}^k(\delta_3)$) denote the (average) payoff agent 3 (opponents) gets at information set k if she opts for action $\delta_3 \in \{0,1\}$. Clearly, (in contrast with (10)), $\pi_l^k, l \in \{3,-3\}$ is a random variable, with

[12] See, e.g., Binmore et al. [1], Bolton [2], , Bolton and Ockenfels [3], Cabrales et al. [4], Fehr and Schmidt [7] and Ochs and Roth [10].

mean $\mu_l^k((\delta_3))$ and variance $\sigma_l^k(\delta_3)$. We shall postulate a utility function of the following form:

$$u_3^k(\delta_3) = \gamma_1^k \mu_3^k(\delta_3) + \gamma_2^k \mu_{-3}^k(\delta_3) + \gamma_3^k \sigma_3^k(\delta_3) + \epsilon_s + \varepsilon_s(t) \tag{11}$$

that is, a simple mean-variance utility function which also includes a parameter (γ_2^k) which measure agent 3's responsiveness to the average opponents' payoff. From (11), we derive the following equation:

$$prob(\delta_s^k(t) = 1) = \frac{\exp\left(\gamma_1^k \mu_3^k(1) + \gamma_2^k \mu_{-3}^k(1) + \gamma_3^k \sigma_3^k(1)\right)}{\exp\left(\gamma_1^k \mu_3^k(1) + \gamma_2^k \mu_{-3}^k(1) + \gamma_3^k \sigma_3^k(1)\right) + \exp\left(\gamma_1^k \mu_3^k(0) + \gamma_2^k \mu_{-3}^k(0) + \gamma_3^k \sigma_3^k\right.} \tag{12}$$

where $\Delta\mu_l^k \equiv \mu_l^k(1) - \mu_l^k(0)$ ($\Delta\sigma_3^k \equiv \sigma_3^k(1) - \sigma_3^k(0)$).

Notice some important differences with the estimation procedure proposed by Costa-Gomes and Zauner [6]:

1. We allow $\gamma_m^k, m = 1, 2, 3$ to vary in k, that is, across information sets (although we impose $\gamma_m^2 = \gamma_m^3$ since, by construction, $\pi_l^2(\delta_3) = \pi_l^3(\delta_3)$ for all l and δ_3);

2. we do not impose any equilibrium condition on agents' beliefs (at the cost of restricting our sample to subjects in agent 3's position);

3. we include a parameter (γ_3^k) to take into account the randomness of the payoff function;

4. our regression (12) also includes an individual random effect (ϵ_s).

Insert Figure 13 about here

Figure 13 contains the estimations of two alternative equations based on (12). Equation (1) estimates the nested model which imposes the restriction $\gamma_m^1 = \gamma_m^2 = \gamma_m^4 \equiv \gamma_m$ (i.e. by analogy with Costa-Gomes and Zauner [6], equation (1) is based on the assumption that γ_m^k is constant in k). In this case, all coefficients are significant, that is, late-movers show a positive (negative) concern to their own (opponents') payoff and are risk-averse. To check for within-mechanism learning effects we also include the dummy variable $last10_s(t) = 1$ (0) if $t > 10$ ($t \leq 10$) in Equation (1) as a regressor.[13] This time variable is not significant and, in the following equation (2), we shall pool the data over the 20 periods.

In equation (2), we let γ_m^k to vary in k. This yields the following results.

1. As for γ_1, we can accept the null hypothesis $\gamma_1^1 = \gamma_1^4 = 0$ (i.e. γ_1 being constant across information sets). The estimates of γ_2^1 and γ_2^4, both independently and jointly, are not significantly different than 0. In other words, there is a component in subjects' behavior which is well explained by (expected) payoff maximization. In addition, this component seems not to be history dependent.

2. As for γ_2, the picture is rather different. Here the data strongly reject the null hypothesis $\gamma_2^1 = \gamma_2^4 = 0$. In this case, the estimates of γ_2^1 and γ_2^4, both independently and jointly are significantly different than 0. Moreover, they are also significantly different to each other, showing a higher concern to the opponents' payoff associated to higher investment on their behalf. We interpret this result as an evidence of *the predominance of the social norm over the social preference effect.*

3. Also the estimates γ_3^k are not constant in k. In particular, subjects display a lower degree of risk aversion the closer they find themselves to the efficient path (although the marginal effect is always negative).

5 Conclusion

Our experimental results have an immediate implication in the context of peer effects. In many organizations agents' effort exertion generates positive externalities on their peers. This can either emerge from the technology itself in the sense that agents' tasks are complementary, making one agent's effort more effective when the other exert effort as well, or it can be a pure psychological effect that induces agents to mimic the effort behavior of others. In either cases, our results indicate that creating moderate asymmetry

[13] We also considered dummy variables to check for *inter-treatment* learning effects (that is, associated to the sequence of treatments within a session). These variables turned out to be never significative, neither individually nor jointly, and have been omitted in the final estimations. The same considerations hold for variables related to subjects´ previous (or cumulated) payoffs.

by endowing some agents with more stake in the success of the project can be effective in boosting effort.

Our experiment also shows that, despite a significant evidence of out-of-equilibrium ("irrational") play, *incentives matter* in the characterization of the aggregate play and that subjects react "strategically" to the competing implementation schemes. In other words, our experimental evidence can be fruitfully applied to help the principal in enhancing efficiency of the mechanism design solution.

In this respect, our results on the good performance of simultaneous mechanisms, as well as on the role of social preferences and reciprocity, raises interesting questions for the mechanism designer. This is exactly the route followed by Cabrales *et al.* [4], who characterize Winter's [14] optimal solution to a (more general) strategic environment in which agents are allowed to hold social preferences a' la Fehr and Schmidt [7].[14] By analogy with Winter [14], Cabrales *et al.* [4] only deal with simultaneous mechanisms. In this respect, together with SNASH (with social preferences), they also consider an alternative mechanism (they call it *wini*) which only requires the optimal (all-effort) solution being a Nash equilibrium of the induced game, not necessarily the only one. This, in turn, implies that, contrary to SNASH, the induced linear program is characterized by symmetric constraints on players' utility functions (i.e. a symmetric solution): some asymmetry in agents' benefits can arise due to heterogeneity in social preferences. Moreover, since no additional condition is required out of equilibrium, the *wini* solution implies a smaller wage bill for the principal. Consistently with the experimental results we report in this paper, they find that, when asked to act as principals or agents in the game, subjects rarely opt for a *wini* contract, and when they do it, investment in the game is so low to yield, compared with SNASH, significantly lower monetary payoffs for all parties involved. In other words, *when facing the choice between equity and robustness to strategic uncertainty, both principals and agents opt for the latter, and when they don't, they pay the consequences!*

References

[1] Binmore, K. and J. McCarthy and G. Ponti and L. Samuelson and Avner Shaked (2002), "A Backward Induction Experiment", *Journal*

[14]See also Itoh [9] and Rey [11].

of Economic Theory, 104, 48-88.

[2] G.E.Bolton (1991),"A comparative model of bargaining:Theory and evidence", *American Economic Review,* 81,1096 –1136.

[3] Bolton, G and A.Ockenfels (2000), "ERC:A theory of equity,reciprocity and competition", *American Economic Review*, 90, 166 –193.

[4] Cabrales A., Miniaci R., Piovesan M. and G. Ponti (2006), *An Experiment on Markets and Contracts: Do Social Preferences Determine Corporate Culture?*, Universidad de Alicante, mimeo.

[5] Camerer, C. and E. Fehr (2001), *Measuring social norms and preferences using experimental games: A guide for social scientists,* Institute for Empirical research in Economics - University of Zurich WP 97.

[6] Costa-Gomes, M. and K. G. Zauner (2001), "Ultimatum Bargaining Behavior in Israel, Japan, Slovenia, and the United States. A Social Utility Analysis", *Games and Economic Behavior* 34, 238-269.

[7] Fehr, E. and K.M.Schmidt (1999), "A theory of fairness,competition and cooperation", *Quarterly Journal of Economics*, 114, 817 –868.

[8] Fischbacher, Urs (1999), *z-Tree. Toolbox for Ready-made Economic Experiments*, IEW Working paper 21, University of Zurich.

[9] Itoh, H. (2003), *Moral Hazard and Other-Regarding Preferences*, Hitotsubashi University, mimeo.

[10] Ochs, J. and A. E. Roth (1989), "An experimental study of sequential bargaining", *American Economic Review*, 79, 355-385.

[11] Rey, P. (2004). "Inequity aversion and team incentives," University College London, mimeo.

[12] Shleifer, A. and R. W. Vishny (1997) "A survey of Corporate Governance", *Journal of Finance,* 52, 2, 737-783.

[13] Winter, E. (2002), *Scapegoats and Optimal Allocation of Responsibility*, Hebrew University of Jerusalem, mimeo.

[14] Winter, E. (2004), "Incentives and Discrimination", *American Economic Review,* 94, 764-773.

6 Appendix. Experimental instructions (Treatment 1)

6.1 SCREEN 1

WELCOME TO THE EXPERIMENT !

- This is an experiment to study how people solve decision problems.
- We are only interested in what people do on average, and keep no record at all of how our individual subjects behave.
- Please do not feel that any particular behavior is expected from you. On the other hand, keep also in mind that your behavior will affect the amount of money you will earn.
- On the following you will find a series of instructions explaining how the experiment works and how to use the computer during the experiment.
- Please do not disturb the other subjects during the course of the experiment. If you need any help, please raise your hand and wait silently. You will be assisted shortly.

6.2 SCREEN 2

- Note that you have been assigned a PLAYER number.
- This represents your player position in a sequence of three (PLAYER 1 moves first, PLAYER 2 moves second, and PLAYER 3 moves last).
- Moreover, PLAYERS observe the decisions of those who have previously moved. That is, PLAYER 3 observes the decision of PLAYER 2 and PLAYER 1; PLAYER 2 observes the decision of PLAYER 1, while PLAYER 1 does not observe the decisions of the other PLAYERS.
- Your PLAYER position will remain the same throughout all the experiment. Also the composition of your group (that is, the other two persons that interact with you, with different PLAYER position) will remain the same throughout the experiment.

6.3 SCREEN 3

HOW YOU CAN MAKE MONEY

- The experiment will consist of three sessions with 20 rounds each.
- Assume that, at every round, your group has to carry out a "project". A project consists in a task for each PLAYER. You will receive a certain amount of money (depending on your PLAYER position) on top of your "base salary" of 150ptas only if the project succeeds. How much money you earn if the project succeeds is shown in the Figure on your left. For example, if the project is done successfully PLAYER 2 will receive 150 + 120 = 270 ptas.

6.4 SCREEN 4

THE GAME

- Each PLAYER works together with a "computer assistant". The role of the assistant is simply to implement the PLAYER's decision at the project's location. If the computerized assistant receives a phone call from you at the cost of 100ptas, the computer will implement your decision EXACTLY. If not, it will choose an action at random, with each action being equally probable.
- The project succeeds only if each PLAYER carries out her task correctly. Your task is to choose between three actions: "A", "B", "C", with "A" denoting the correct course of actions to complete your task. You know it. The problem is that, if you do not make the phone call (and pay for it out of your salary), your computer assistant cannot make the right decision with certainty.

6.5 SCREEN 5

THE GAME (II)

To summarize:

- Each PLAYER has simply to decide, in each round, whether to call the computer assistant or not. The cost of the call is the same for all PLAYERS (100pts).
- If a PLAYER makes the phone call, her computerized assistant will make the right choice ("A") with certainty. If a PLAYER does not make the phone call, the probability with which the computer assistant will make the right action is 1/3.

- The project succeeds only if all PLAYERS (that is, their "computerized assistants") select the right action ("A"). If so, each PLAYER will be paid the "base salary" plus a "bonus" according to the matrix on your left minus the cost they may have paid for the phone call.
- If the project does not succeed then all the PLAYERS will just be paid the based salary (150pts) minus the cost they may have paid for the phone call.

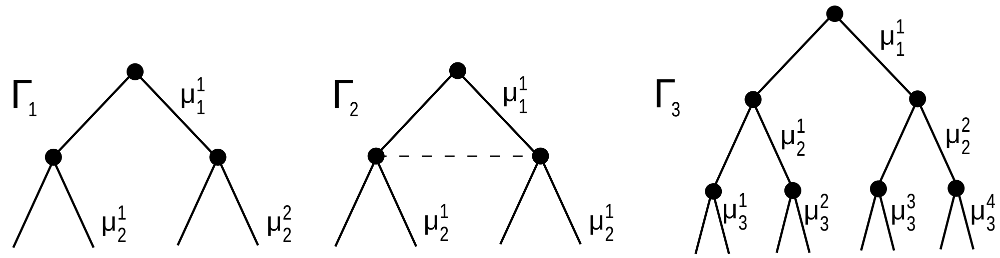

Figure 6

	Regressors									
EQ	γ_1	γ_1^1	γ_1^4	γ_2	γ_2^1	γ_2^4	γ_3	γ_3^1	γ_3^4	$last10$
(1)	0.481 (0)			-0.066 (0)			-0.032 (0)			0.092 (0.491)
(2)	0.504 (0)	0.472 (0.154)	-0.093 (0.516)	-0.761 (0)	-2.343 (0)	0.702 (0)	-0.011 (0.266)	-0.069 (0.004)	0.004 (0.712)	**0**

Figure 13